Geomorphic and Aqueous Chemistry of a Portion of the Upper Rio Tinto System, Spain. M. R. Osburn[1], D. C. Fernández-Remolar[2], R. E. Arvidson[1], R. V. Morris[3], D. Ming[3], O. Prieto-Ballesteros[2], R. Amils[2], T. C. Stein[1], V. Heil-Chapdelaine[1], L. R. Friedlander[1], B. Herndon[1], J. Marlow[1], S. Rosenberg[1], K. Schepker[1], and A. Steiner[1], [1]Dept. of Earth and Planetary Sciences, Washington University, St. Louis, MO, 63130, [2]Centro de Astrobiología, Torrejón de Ardoz, Spain, [3]NASA Johnson Space Center, Houston, TX, 77058.

Introduction: Observations from the two Mars rovers, Spirit and Opportunity [1,2], combined with discoveries of extensive hydrated sulfate deposits from OMEGA [3-6] and CRISM [7] show that aqueous deposition and alteration involving acidic systems and sulfate deposition has been a key contributor to the martian geologic record. Rio Tinto, Spain, provides a process model for formation of sulfates on Mars by evaporation of acidic waters within shallow fluvial pools, particularly during dry seasons [8]. We present results from a detailed investigation of an upper portion of the Rio Tinto (Fig. 1), focusing on geomorphology, clastic sediment transport, and acidic aqueous processes. We also lay out lessons-learned for understanding sulfate formation and alteration on Mars.

Study Sites and Methodology: We investigated a ~1 km long section of the upper Rio Tinto where the river is a 2nd order stream (see Fig. 1). This portion of the river system is narrow (~10 m wide) and confined between high (10's of m) bedrock-cored ridges covered with weathered rock and colluvium. Colluvial and alluvial materials can be found close to and interfingering with the Rio Tinto and its narrow flood plain deposits. Water flow within the river is markedly seasonal. Hot dry summers reduce the river to a series of acidic evaporative pools. Our first study region, Mrs. White's Garden, is a ~20 m by 20 m portion of the river with extensive flat areas and multiple evaporating pools. We reported last year on the ensemble of copiapite-dominated evaporite deposits forming in this portion of the river [9]. The second site, Professor Plum's Palace (Fig. 2), is marked by a fault (perhaps influenced by volume changes associated with sulfate dissolution) and/or erosional nick-point exposing an older terrace cross-section oriented in a direction perpendicular to the river [10]. Professor Plum's Palace was the focus of our field deployment in September 2006. Methods of study included panoramic and close-up imaging, field-based reflectance spectroscopy, on-site XRF and XRD using a prototype instrument for the Mars Science Laboratory's CHEMIN [11], and biological assays of samples likely to exhibit microbial life using the SOLID system [12]. Key samples were also collected and returned to the laboratory for further analyses.

Interplay Between Geomorphic and Aqueous Processes: The modern evaporative system in which copiapite-dominated sulfates form as pools evaporate was in fact observed during the course of a single day.

For example, most of the copiapite growths shown in Fig. 3 developed during one day as the acidic pool evaporated. We also investigated other pools, although we did not track when the minerals were produced. We found one pool produced dominantly gypsum upon evaporation. In addition, Jarosite was found in very shallow pools that evaporated to produce a thin, pinkish coating. All of these sulfate minerals formed in the modern fluvial-evaporative system and were deposited onto goethite-cemented conglomerates that dominate the river bottom and floodplain and include slag cobbles produced by mining within the past two centuries. The presence of goethite-cemented cobbles of anthropogenic origins shows that the conversion from sulfates to goethite occurs over a very short interval, presumably during rainfall periods when water pH rises above 4, which favors sulfate dissolution in deference to goethite formation. In fact, the 2 m high terrace exposed perpendicular to the river was dominated by goethite-cemented, poorly sorted conglomerates with no slag (Fig. 4). This demonstrates the interaction between clastic transport, sulfate formation, subsequent dissolution, and cementation by goethite to build up the fluvial record. Interestingly, most of the colluvium and alluvium bounding the river was not mineralized by sulfates or goethite. Nor was a fluvial terrace exposed by bank erosion. Rather these materials were largely fine-grained overbank deposits formed during floods. Further, radiocarbon dates place these materials as pre-modern (older than 1500 years B. P.) and thus not influenced by water storage and other mining activities that impacted river flow and chemistry. It is the center of the river, with acidic flows from the ore bodies up stream, that is subjected to sulfate formation by evaporation and subsequent conversion to goethite that cements and preserves the clastic fluvial conglomerates transported from the surrounding hills and upstream.

Lessons for Understanding Martian Sulfates: Two examples are provided in this abstract. First, Meridiani sulfates are quite uniform in their composition and mineralogy [2]. This has been explained by a widespread rise of acidic ground waters and formation of evaporitic pools with clastics homogenized and supplied by aeolian processes [13]. In contrast to our 2nd order Rio Tinto stream, colluvium and alluvium deposits dominated by neutral waters from surrounding hills was not a major process in forming the Merid-

iani deposits. Second, the highest abundance of sulfur was in fact detected by Spirit for light-toned soils disturbed during driving (e.g., Paso Robles, Arad, Tyrone). These materials tend to be found in saddles between the Columbia Hills. One interpretation is that the sulfates formed by leaching of the hills with formation of evaporites as the groundwaters came to the surface at the distal portions of the hills. This is just the opposite of what we found in Rio Tinto and may simply be a consequence of the source of acidic waters (hills on Mars and acidic waters from upstream ore bodies for Rio Tinto).

Figure 1: Portion of an IKONOS color image showing the study area along an upper portion of the Rio Tinto. Note the steeply dipping slopes that bound the river. Image width is 1.2 km. Located just to the north of Nerva, Spain.
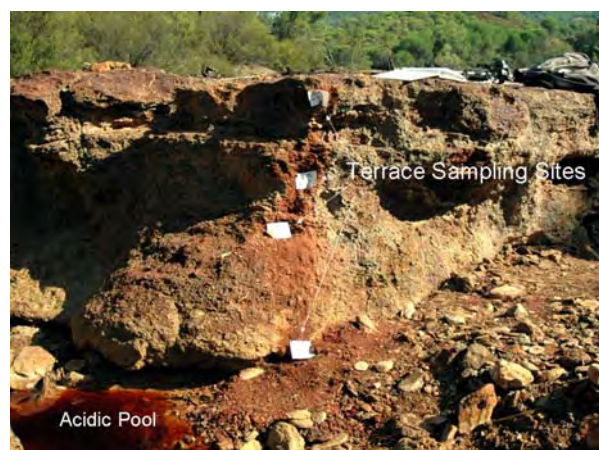

Figure 2: Terrace exposed perpendicular to river at Professor Plum's Palace generated by faulting and/or as a fluvial nick point in a constricted portion of the Rio Tinto.

Figure 3: Copiapite efflorescent salts growing from an evaporating pool of water on 9/5/06 at Professor Plum's Palace.
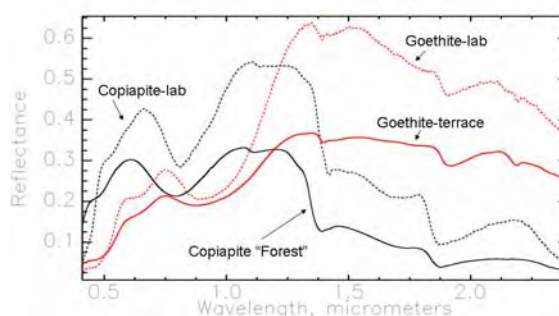

Figure 4: Field reflectance spectra for one of the copiapite growths shown in Fig. 3, together with a lab-based spectrum of copiapite from the USGS (courtesy Roger Clark). Also shown is a spectrum for the top of the terrace shown in Fig. 2 and a USGS lab-based spectrum for goethite. The difference between the ~1 micrometer absorptions for the field and lab spectra are probably a consequence of the variety of copiapite-group minerals found in Rio Tinto.

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